10/532817
JC12 Rec'd PCT/PTC 26 APR 2005

DEVICE FOR IMAGE PROCESSING WITH RECOGNITION AND SELECTION OF LIGHT SOURCES

The field of the invention is that of devices for processing images making it possible to identify, to process and to select representations of discrete light sources present in a video image composed of pixels. The object of these devices is the presentation, in real time, to a user of a processed image allowing better recognition of representations of weakly contrasted light sources.

Aeronautics constitutes a favored field of application of this type of device in so-called EVS (Enhanced Vision System) systems by affording an effective aid to landing in conditions of degraded visibility, in particular in foggy weather. Specifically, to land, it is vital that the pilot or the landing aid system should be aware of the lateral position of the machine with respect to the ideal trajectory bringing the machine onto the axis of the runway.

Historically, when flying by sight and in clear weather, the pilot would estimate the position of his machine with respect to the edges of the runway. The introduction of airport lights, of codified structure, consisting of high intensity runway lamps has allowed the pilot to undertake this task even when flying at night or in slightly foggy conditions. When the meteorological conditions degrade further, for example in conditions of severe fog with visibility of less than 200 meters, these systems are no longer adequate.

The ILS (Instrument Landing System) has been used since 1970 to provide the pilot and the automatic pilot, with the aid of two fixed radio frequency beams, with the necessary lateral positioning information. Nowadays, new systems are envisaged, such as MLS (Microwave Landing System) derived from ILS but allowing a greater

variety of approaches, or systems based on GPS (Global Positioning System) or a GPS/inertial platform hybridization. The common constraint shared by these various systems is the need to install additional equipment on the ground and aboard the machine to achieve the necessary positioning accuracy. The certifying authorities demand, in fact, an accuracy which is typically of the order of three meters. These installations (differential GPS station, MLS transmitter, etc.) incur additional acquisition and maintenance costs which may be very significant for certain lightweight airport infrastructures dedicated, for example, to regional and business airplanes or to military transport machines.

So-called EVS (Enhanced Vision System) manual landing aids make it possible to alleviate the absence of radiofrequency systems for aiding the approach. Figure 1 represents the general diagram of an EVS chain. It comprises an image sensor 2, an image processing device 1 and a viewing device 3. An observer 4 looks at the final image through said device 3. A specialized electronic unit 100 providing the position and the attitude of the aircraft is interfaced with the image processing unit 1. Links 21, 31 and 101 connect the various components of the system. The sensor 2 provides an image in a spectral band matched to the light sources to be detected. This is generally an FLIR (Forward Looking InfraRed). In the case of runway lamps having their emission peak around 1 micron, the sensor's spectral sensitivity band is therefore situated in the near infrared, at the limit of the visible spectrum. The unit 100 makes it possible to compare the alteration of the parameters of the image with the real displacements of the aircraft. The viewing device is conventionally a head-up viewfinder, making it possible to display the final image provided by the processing device 1 superimposed on the exterior, this disposition makes it possible to project

the image of the runway lamps estimated in the actual directions of said lamps, the pilot thus being aware of his position with respect to the ideal landing trajectory.

This first imager may usefully be supplemented with a second FLIR imager working in a second infrared band lying, for example, between 8 and 12 microns. This second imager then provides a thermal image of the landing zone.

Two parameters make it possible to judge the quality of the processing device. These are on the one hand, the percentage of runway lamps identified and on the other hand the percentage of artifacts not corresponding to real runway lamps.

The main difficulties of the image processing are that the latter must work in real time so that the pilot perceives an image corresponding to reality without a notable time shift, thereby excluding any sophisticated processing of the image, and on the other hand, the processing must preserve its performance rating for images, that are by nature variable.

The image processing device according to the invention makes it possible to alleviate these various drawbacks. The core of the invention relies on three principles:

- the main processing of images is performed only on a small number of pixels whose level is greater than a threshold;
- a likelihood estimator evaluates the probability of existence of light sources in the image;
- the threshold is variable as a function of a certain number of parameters of the image.

More precisely, a subject of the invention is an electronic device for image processing generating an output image from an input image, the two images being

composed of pixels, the input image originating from a first video sensor and representative of a scene containing at least one discrete light source, said input image containing a first representation of said discrete light source, the output image comprising a second representation of said discrete light source, characterized in that said device comprises at least:

- an electronic unit for improving contrast making it possible to provide on the basis of the input image an image with better contrast;
- an electronic unit for selection making it possible to provide on the basis of the image with better contrast a filtered image now containing only at least a first set of pixels whose electronic level is situated above a first threshold, said first set corresponding to the representation of at least one potential light source;
- an electronic likelihood estimation unit, making it possible to provide on the basis of the first set of pixels of the filtered image an estimated image comprising a second set of pixels, said second set corresponding to the representation of estimated light sources, the distributions of the pixels of the representations of the estimated sources corresponding to bidimensional mathematical functions; with each representation of estimated light source there being associated a likelihood probability;
- an electronic unit for validation providing on the basis of the estimated image the final image, said image containing a representation of the estimated light source if the associated likelihood probability is greater than a second threshold.

Advantageously, the level of the first threshold depends at least on said validation unit.

Advantageously, said electronic function for improving

the contrast of the initial input image comprises at least one matrix filter of CBF (contrast box filter) type applied to each pixel level of the initial input image to obtain the contrasted input image. Said matrix is in particular a square matrix of M rows and M columns of elements, the N central elements having one and the same first value, the other (M^2-N) elements of the matrix having one and the same second value equal to said first value multiplied by $N/(N - M^2)$.

The main functions of the estimator are:

- the electronic function for recognition of the shape of the representation of the light sources,
- the electronic function for recognition of the geometrical disposition of said representations of said sources,
- the electronic function for estimation of displacement of said representations of said sources.

The electronic function for recognition of the shape of the representation of the light sources makes it possible:

- to compare the levels of the pixels of the first set of the filtered image with calculated levels, emanating from predetermined mathematical functions
- to provide a probability of presence of the representation of the estimated light source in the input image.

Advantageously, predetermined mathematical functions are bidimensional Gaussians and the recognition function is effected by application of the method of least squares between the levels of the pixels of the first set and the calculated levels.

The electronic function of recognition of the geometrical disposition of said representations of the

sources provides a probability of alignment of said representations of the light sources in the input image. When the representations of the potential sources are aligned along at least one straight line, the electronic recognition function comprises at least one function making it possible to effect a radon transform on the pixels of the filtered image.

When representations of the sources are mobile in the input image, the electronic likelihood estimator comprises at least one electronic function for modeling displacement of the representations of the estimated sources. It also comprises at least one electronic function for estimating displacement making it possible, on the basis of the electronic function for modeling displacement of the representations of the estimated sources:

- for each representation of estimated light source of a first estimated image occupying a first position, to calculate the theoretical displacement of said first position;
- to calculate a second position occupied by said representation of the estimated light source in a second estimated image;
- to compare said second position with the real position of said representation of the light source in said second estimated image.
- to provide a probability of displacement of the representation of the source in the estimated image.

Advantageously, the probability of the likelihood of a representation of the estimated light source provided by the electronic unit for validation is equal to the product of the probabilities of presence, of alignment and of displacement of said representation of the light source that are provided by the electronic estimation unit. The electronic unit for validation calculates a rate of rejection of the input image equal to the

percentage of representations of estimated sources whose likelihood probability is situated above the second threshold over the total number of representations of estimated sources.

Advantageously, the device comprises an electronic histogram unit making it possible to construct the histogram of the pixels of the image with better contrast, said histogram comprising for each pixel level the corresponding number of pixels. Said electronic histogram unit comprises a function making it possible to determine a third threshold, the level of said third threshold being situated above the mean level of the pixels of the filtered image and below the mean level of the pixels of the representations of the potential light sources. Advantageously, the histogram being represented in the form of a graph having as abscissa the level of the pixels and as ordinate the number of pixels corresponding to this level, the level of the third threshold corresponds to the level which lies at the largest distance from the straight line passing through the maxima in abscissa and in ordinate of this graph.

Advantageously, the device comprises an electronic unit called a recursive filter which determines for a second input image subsequent to a first input image, the value of the first threshold to be applied to this second image, the value of said first threshold of this second image depending at least on the value of the first threshold, of the third threshold and of the rate of rejection of the first input image.

In a principal mode of application, the final image is projected in a viewing system superimposed with an image originating from a second sensor. Preferably, the first sensor is sensitive in the near infrared in the 1 to 2 microns band and the second sensor is sensitive in the middle infrared in the 5 to 20 microns band.

Advantageously, the device is integrated into a viewing system comprising at least one video sensor, the electronic device for image processing and a viewing device, means for locating the position and orientating the video sensor in space, said locating means being interfaced with said processing device, it being possible to render said system mobile, for example by being mounted on a vehicle.

The aeronautical field constitutes a favored application of this type of device. Within this framework, the vehicle is an aircraft and the light sources are runway lamps, the first sensor is sensitive in the near infrared in the 1 to 2 microns band and the second sensor is sensitive in the middle infrared in the 5 to 20 microns band.

The invention will be better understood and other advantages will become apparent on reading the description which follows given without limitation and by virtue of the appended figures among which,

- figure 1 represents the general diagram of an image acquisition, processing and presentation chain;

- figure 2 represents a basic view of the processing device according to the invention;

- figure 3 represents a detailed basic view of the processing device according to the invention;

- figure 4 represents the principle of the determination of the third threshold in the graph of the histogram of the pixel levels.

Figure 2 represents a basic view of the processing device according to the invention. It essentially

comprises four electronic units namely:

- an electronic unit for improving contrast 5 making it possible to provide on the basis of the input image an image with better contrast;
- an electronic selection unit 6 making it possible to provide on the basis of the image with better contrast a filtered image;
- an electronic likelihood estimation unit 7, making it possible to provide an estimated image from the filtered image;
- an electronic validation unit 8 providing the final image from the estimated image.

The unit 5 is interconnected with the sensor 2 by means of the link 21. The unit 7 is interconnected with the device 100 by means of the link 101. The unit 8 is interconnected with the viewing device 3 by means of the link 31.

Figure 3 represents a detailed view of the principle of the device in figure 2. Certain electronic units are detailed, complementary units are appended.

In the two figures 2 and 3, the arrows indicate the interconnections between the various units and the direction of their data exchange.

The electronic unit for contrast improvement makes it possible to boost the contrast of the image. Various procedures exist. A simple way of obtaining this effect is to use a matrix filter of CBF (contrast box filter) type applied to each pixel level of the initial input image so as to obtain the contrasted input image. The matrix of this filter is a square matrix of M rows and M columns of elements, the N central elements having one and the same first value, the other (M^2-N) elements of the matrix having one and the same second value equal to said first value multiplied by $N/(N - M^2)$. At a given pixel P of the input image having a certain

level, one obtains the level of the corresponding pixel in the image with better contrast by doing the following operations:

- multiplying the values of the M^2 pixels surrounding the pixel P by the values of the corresponding elements of the matrix of the filter, the matrix being centered on the pixel P;
- summing the M^2 values obtained so as to obtain the value of the pixel of the image with better contrast.

By way of example, a typical matrix comprises 7 rows and 7 columns, or a total of 49 elements the 9 central elements being equal for example to 1 and the other 40 elements then being equal to -9/40. The resulting matrix of the filter is represented hereinbelow:

-9/40	-9/40	-9/40	-9/40	-9/40	-9/40	-9/40
-9/40	-9/40	-9/40	-9/40	-9/40	-9/40	-9/40
-9/40	-9/40	1	1	1	-9/40	-9/40
-9/40	-9/40	1	1	1	-9/40	-9/40
-9/40	-9/40	1	1	1	-9/40	-9/40
-9/40	-9/40	-9/40	-9/40	-9/40	-9/40	-9/40
-9/40	-9/40	-9/40	-9/40	-9/40	-9/40	-9/40

The electronic selection unit 6 preserves the pixels of the image with better contrast whose level is situated above a first threshold, the level of the other pixels being reduced to 0. The filtered image thus now contains only a first set of pixels corresponding to potential light sources.

The electronic likelihood unit can comprise 3 units as is indicated in figure 3.

The first of these units 71 is tasked with the recognition of the shape of the light sources. In the general case, the sources being situated a large distance from the image sensor, their representations

ought to appear as luminous sets of small dimension, covering at most a few pixels. A good mathematical representation of the distribution of the energy of the representation of the source, in this case, is a bidimensional Gaussian. The unit responsible for identifying the representations of the potential sources compares the levels of the distributions of pixels of the filtered image with those of a bidimensional Gaussian representation by varying four parameters: the level of the Gaussian, its width at mid-height along a first axis, its width at mid-height along a second axis perpendicular to the first, the inclination of the first axis in the reference frame of the image. The comparison is done by applying the method of least squares between the levels of the pixels of the first set and the calculated levels of the Gaussian. The residual error of the optimization procedure makes it possible to estimate the probability of presence of a source representation. When this probability is greater than a certain threshold, the representation of the potential source is replaced in the estimated image with its Gaussian representation. It should be noted that this procedure makes it possible to determine the position of the representations of the sources with an accuracy of less than a pixel.

The second of these units 72 is tasked with the recognition of the geometrical disposition of the representations of the sources. In an aeronautical application, the runway lamps are disposed according to codified geometrical structures representative of the runway axes which are straight lines or straight line segments. The second unit makes it possible to search for the presence of such structures in the filtered image. The mathematical function used is a radon transform. The principle thereof consists in searching the image for the favored directions where the mean energy of the pixel is significant and may consequently

correspond to axes of alignment of light sources.

The third of these units 73 is tasked with providing a probability of displacement of representations of the light sources. Said specialized unit is used either when the sources present in the scene are displacing in a known manner, or when the device is located on a moving vehicle and when the displacements and the orientation of the vehicle are known; this being the case for aircraft. As input data it has, on the one hand, the knowledge of the initial positions of the representations of the estimated sources in a first filtered image and on the other hand, the information from an electronic unit providing a displacement model 9. For a moving vehicle, this model is interfaced with the vehicle's locating means 100. It calculates the second positions occupied by said representations of the estimated light sources in a second input image. It compares said second positions with the real positions of said representations of the light sources in the second input image. It then provides a probability of displacement of the representations of the sources.

The unit 8 undertakes the following tasks:

- calculating the probability of likelihood of a representation of estimated light source which is equal to the product of the probabilities of presence, of alignment and of displacement of said light source that are provided by the electronic estimation units 71, 72 and 73.
- eliminating from the estimated image the representations of the estimated sources whose likelihood probability is situated below the second threshold. The second threshold is equal to around 95% so as to construct the final image, said final image being provided at the viewing device.
- calculating a rate of rejection of the input image equal to the percentage of representations of

sources present in the final image over the total number of representations of sources present in the estimated image.

- providing the unit 6 with the calculated rejection rate.

When the rejection rate is low, this signifies that all the representations of estimated sources correspond to real sources present in the scene and consequently, the level of the first threshold is too significant. When the rejection level is significant, it is necessary, on the contrary to raise the threshold level which is too low.

Two additional electronic units figure in figure 3. The unit 10 is a unit making it possible to construct the histogram of the pixels of the image with better contrast, the graph of the histogram H represented in figure 4 comprises as abscissa the level of the pixels and as ordinate the number of pixels corresponding to this level. Said electronic histogram unit comprises a function making it possible to determine a third threshold B, the level of said third threshold being situated above the mean level A of the pixels of the contrasted image and below the mean level C of the pixels of the representations of the potential light sources. The level of the third threshold B corresponds to the level which lies at the largest distance d from the straight line MD passing through the maxima in abscissa D and in ordinate M of the graph of the histogram H.

The unit 11 called a recursive filter determines for a second input image subsequent to a first input image, the value of the first threshold to be applied to this second image, the value of said first threshold of this second image depending at least on the value of the first threshold, of the third threshold and of the rate of rejection of the first input image. It comprises a

low-pass filter for stabilizing the system making it possible to avoid overly abrupt variations of the final image. Its cutoff frequency is less than 5 Hz.

The whole set of functions of the electronic units may be implemented in electronic components comprising matrices of logic gates (AND or OR). These components may be of nonprogrammable type such as, for example, ASICs (Application Specific Integrated Circuits); in this case, the information is burnt into the circuit during construction. These components may also be programmable such as, for example, FPGAs (Field Programmable Gate Arrays) or EPLDs (Erasable Programmable Logic Devices). These components are commonly used for applications of professional electronics or aboard aircraft.